CONTINUOUS PROCESS FOR PRODUCTION OF STEEL PART WITH REGIONS OF DIFFERENT DUCTILITY

SPECIFICATION

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for heat-treating a steel workpiece. More particularly this invention concerns the production of a steel part having regions of different grain structure and/or ductility.

BACKGROUND OF THE INVENTION

It is known to make various motor-vehicle parts - e.g. tie rods, B-columns, struts, door beams - of hardened steel with uniform ductility and grain structure throughout the entire workpiece. This is accomplished by a heat treatment of the part, raising it to a predetermined temperature and then quenching it in accordance with the desired characteristics of the finished product. The main factor affecting grain structure and/or ductility is the maximum temperature to which the workpiece is heated, that is whether or not it reaches any of several critical temperatures, the so-called AC_1-AC_4 points.

For specific parts, however, it is desirable for the grain structure to vary from one region to another. One region

might need to have exceptional strength while another might need to be able to deform somewhat. This can be accomplished most simply by making the part as a composite of two pieces that are differently treated to have the desired characteristics.

US patent 5,972,134 describes a one-piece part having regions of different ductility. It is produced by heating it locally before deforming it into the desired shape and then cooling it. The disadvantage of this method is that it is a complex batch operation that does not lend itself to the mass production needed for motor-vehicle manufacture.

German utility model 200 14 361 published 16 November 2000 describes a door post or so-called B-column that is rendered austenitic in a furnace and then is simultaneously deformed and quenched in a die. Some parts of the workpiece are insulated before it is put in the furnace so that they do not become austenitic and thus do not when hardened develop a martensitic grain structure. Such a process is also unwieldy, involving the application and removal of insulation before and after the heat treatment, two extra steps that considerably elevate the cost of the workpiece.

For mass production of parts it is standard to use a continuous furnace through which the parts move along a path on a conveyor. US patent 4,622,006 describes such a continuous-heating furnace which is provided with means for taking out and inserting workpieces at several locations along the treatment path. Thus it is possible, with a continuously operating

furnace, to differently heat treat different workpieces, some staying in the furnace for the full treatment and others only being heated for substantially less time. While this system is indeed very flexible, it does not allow one to produce a single workpiece having regions that are treated differently.

OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide an improved system for producing a workpiece with regions of different grain structure and/or ductility.

Another object is the provision of such an improved system for producing a workpiece with regions of different grain structure and/or ductility which overcomes the above-given disadvantages, that is which allows such workpieces to be produced in a simple and continuous process that lends itself to a low-cost mass-production operation.

SUMMARY OF THE INVENTION

According to the invention the interior of a furnace is partitioned into two longitudinally extending and transversely adjacent zones, and one of the zones is heated to a substantially higher treatment temperature than the other of the zones, which may or may not be heated. A steel workpiece is conveyed longitudinally through the furnace with a region of the workpiece

moving exclusively through the one zone and another region of the workpiece moving exclusively through the other of the zones such that the regions are heated to different temperatures.

This method can be carried out on an unhardened workpiece or on one that has already been hardened. In the former case, part of the workpiece is hardened and part of it is either left untreated, or hardened less. In the latter case a part of the workpiece is heated sufficiently to soften or anneal it, and the remainder is left in its hardened condition. Either way, the result is a workpiece with adjacent regions of different hardness/ductility.

The treatment temperatures in the two furnace zones are selected according to the desired workpiece characteristics. When for example a motor-vehicle B-column is being made its foot should be quite ductile so that, in an accident, it can bend at its lower end without breaking off. The shaped part is thus moved through the furnace with its foot in the lower-temperature zone. The zone with the foot is maintained below the AC_1 point (the temperature at which austenite begins to form) and the zone with the rest of the post is maintained above the AC_3 point (the temperature at which all the ferrite has been transformed to austenite). After heat-treatment according to the invention, the workpiece is subjected to the normal hardening steps, e.g. simultaneous quenching and clamping in a die. Thus the foot in the other zone is left ductile, as its grain structure will

remain substantially unchanged, while the balance of the post is very strong.

According to the invention the treatment temperature in one of the zones can be above the AC_1 point for the workpiece and the temperature in the other of the zones below the AC_1 point for the workpiece. This is ideal for a workpiece, e.g. a strip, that has been partially hardened before the zone-wise treatment according to the invention.

It is also possible simply to leave the other zone unheated. This is done when the workpiece has its final shape and merely needs to be hardened in one region. The other zone is thus generally at ambient temperature, below anything that would affect the grain structure of steel.

Also according to the invention the other zone is heated to between the AC_1 point and the AC_3 point of the workpiece and the one zone is heated to above the AC_3 point of the workpiece. Thus there is partial conversion in the low-temperature zone but complete grain-structure conversion in the high-temperature zone.

Steel that has a carbon content greater than 0.8% is treated in another system of this invention where the other zone is heated to slightly below the AC_1 point of the workpiece and the one zone is heated to slightly above the AC_3 point of the workpiece. Thus the low-temperature region is annealed and its grain structure is relaxed.

In order to prevent oxidation of the workpiece, an inert gas is injected into the furnace. The gas can be, for example, nitrogen.

An apparatus for heat-treating a steel workpiece according to the invention thus has a longitudinally extending furnace subdivided internally by partitions into at least two longitudinally extending and transversely adjacent zones. Means such as electrical coils or burners are provided for heating one of the zones to a substantially higher treatment temperature than the other of the zones. A conveyor transports the workpiece longitudinally through the furnace with a region of the workpiece moving exclusively through the one zone and another region of the workpiece moving exclusively through the other of the zones such that the regions are heated to different temperatures.

The furnace normally is of the tunnel type, with a longitudinally throughgoing conveyor made of rollers. The workpieces push each other through the furnace, or the rollers are rotated to advance them. Alternately the furnace can be of the carousel type with an annular path for the workpieces. No matter what the shape of the oven, the partition extends parallel to the path of movement of the workpieces through it.

The partitions in accordance with the invention include a longitudinally extending upper partition above the transport means and a longitudinally extending lower partition below the transport means and vertically aligned with the upper partition.

The upper and lower partitions define a transversely open gap through which the transport means and the workpiece extend.

It is possible for one of the partitions to be displaceable transversely through a plurality of different transversely offset positions. This way the furnace can accommodate differently proportioned workpieces. In this arrangement there can be a plurality of the lower partitions transversely offset from each other and the upper partition is displaceable transversely through positions aligned with each of the lower partitions.

The partitions can also include a middle longitudinally extending partition aligned vertically between the upper and lower partitions. The conveyor means transports the middle partition through the furnace with the workpiece. Thus a complex three-dimensional workpiece can be treated without excessive heat leakage between the furnace zones. This system is particularly applicable to a furnace where the workpiece is carried on a support, typically a plate.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, features, and advantages will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a largely schematic end view of a furnace for carrying out the method of this invention; and

FIGS. 2 through 4 are further views like FIG. 1 of other furnaces in accordance with the invention.

SPECIFIC DESCRIPTION

As seen in FIG. 1 a furnace 1 is internally subdivided by a partition 2 into two zones 1a and 1b. A B-column 3 is moved through this furnace 1 in a direction perpendicular to the plane of the view and is positioned such that one region 3a lies in the zone 1a and another region 3b lies in the zone 1b, the partition 2 of course being slotted to allow the workpiece 3 to be thus positioned. The workpiece 3 is made of hardenable steel with an AC_1 point (the temperature at which austenite begins to form) of 740°C and an AC_3 point (the temperature at which all the ferrite has been transformed to austenite) of 850°C. It is heated in the zone 1a to a temperature of about 700°C and in the zone 1b to a temperature of about 950°C. The workpiece 3 is subsequently worked and ends up having substantially greater strength in the region 3b and greater ductility in the region 3a.

FIG. 2 shows a furnace 4 having a roof 4a from which hangs a short vertical partition 5a and a floor 4b on which stands another short vertical partition 5, with conveyor rollers 6 extending through the gap between the two partitions 5 and 5a. A workpiece 7 is supported on the rollers 6 that are rotated as indicated by the arrow to advance it horizontally through the furnace 4, with one region 7a in a zone 4d to one side of the partitions 4 and 4a and another region 7b in a zone 4c to the opposite side. The zone 4c is cooler than the zone 4d and heat is mainly applied to the zone 4d.

The furnace 8 of FIG. 3 has a top wall 8a with a short depending partition 9, a floor 8d supporting a short partition 9b and rollers 10 that advance a three-dimensional workpiece 12 on a support 11. In order to fill the large gap between the partitions 9 and 9b, a short partition 9a is carried on the support 11 and moved through the furnace 8 with the workpiece 12. Once again, the temperature is different in the zones 3b and 3c defined to opposite sides of the partitions 9, 9a, and 9b.

The furnace 13 of FIG. 4 has a single upper partition 14 depending from a roof 13 and extending parallel to the transport direction which once again is perpendicular to the plane of view. Three further partitions 14a, 14b, and 14c extending parallel to each other and spaced transversely stand on a floor 13b of the furnace 13, with the partition 14a coplanar with the partition 14. Conveyor rollers 15 advance workpieces 16 through the furnace 13. Dashed lines 16a and 16b show how,

instead of planar workpieces 16, three dimensional workpieces can be accommodated.

Thus the furnace is subdivided longitudinally into a compartment 20a to one side of the two partitions 14 and 14a and a compartment 20b to the other side thereof, with the workpiece 16 extending between the chambers. Heaters 17 on the roof 13a and 17a on the floor 13b heat the chambers 20a and 20b to different temperatures. The upper partition 14a can be moved into alignment with either of the partitions 14b or 14c, to which ends gaps 19 and 19a are formed in the roof heater 17, so as to accommodate differently shaped workpieces.

After the workpiece is taken out of any of the above-described furnaces it is typically subjected to a hot-working process or otherwise hardened. The result is that the region treated at lower temperature will have radically different ductility and/or hardness than the region of the workpiece treated at the higher temperature in the furnace. In a situation where one region of the workpiece is not subjected to any further hardening operation, its zone of the furnace is in fact left unheated.